SSL End Product Performance—Correlation from Chip or Device Performance

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Pacific Northwest National Laboratory
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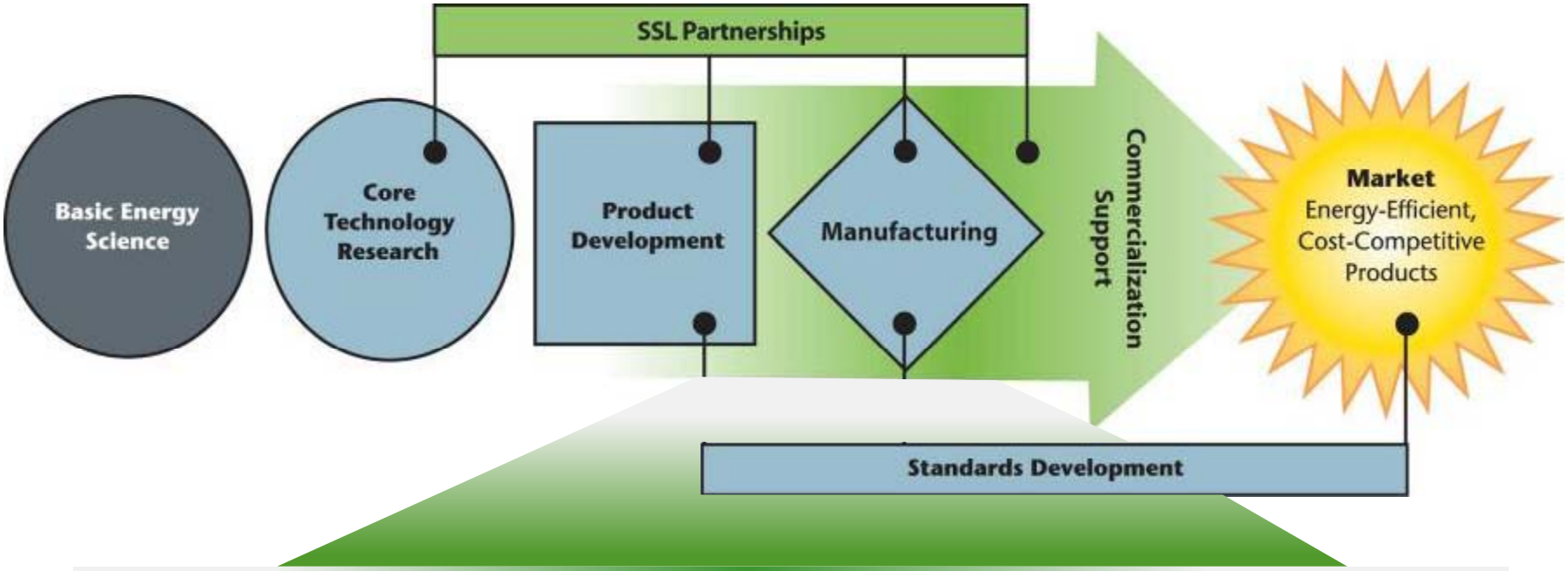
DOE Solid State Lighting Program

Guiding technology advances from laboratory to marketplace



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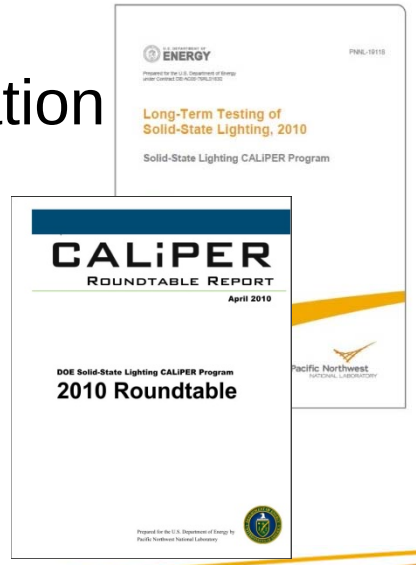
CALiPER Program

- Primary focus of CALiPER
  - Commercially available SSL luminaires and integral lamps
  - Anonymously purchased samples
  - LM-79 testing using qualified independent labs
  - Posting and analyzing test results
- Additional CALiPER testing, studies, coordination
  - Testing and Standards Roundtable Meeting
  - Long-term testing of luminaires and integral lamps
  - Dimming
  - Reliability
  - Flicker
  - Glare



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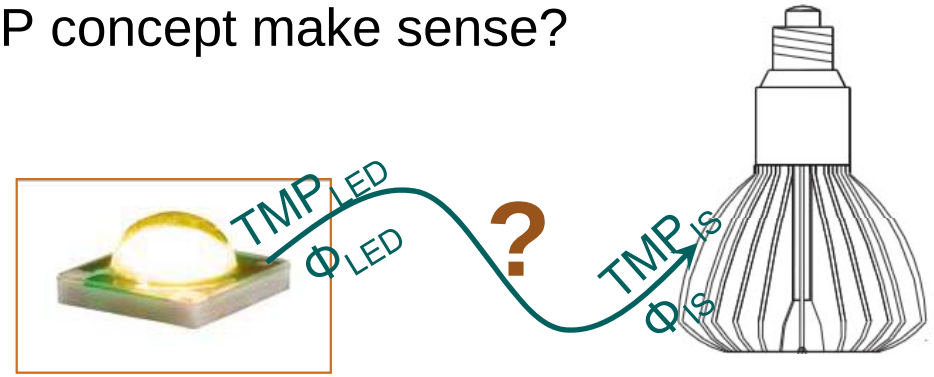
CALiPER Deep-Dive Long-Term Testing

- Hypothesis
  - There is a direct correlation from LED device specs to integral SSL product performance
- What is deep-dive study
  - Examine correlation between device manufacturer design data and *in situ SSL* performance
  - Results will be publicly available
- Why
  - Need to fill gap in standards
  - Provide data and knowledge for standards efforts
  - Does TMP concept make sense?



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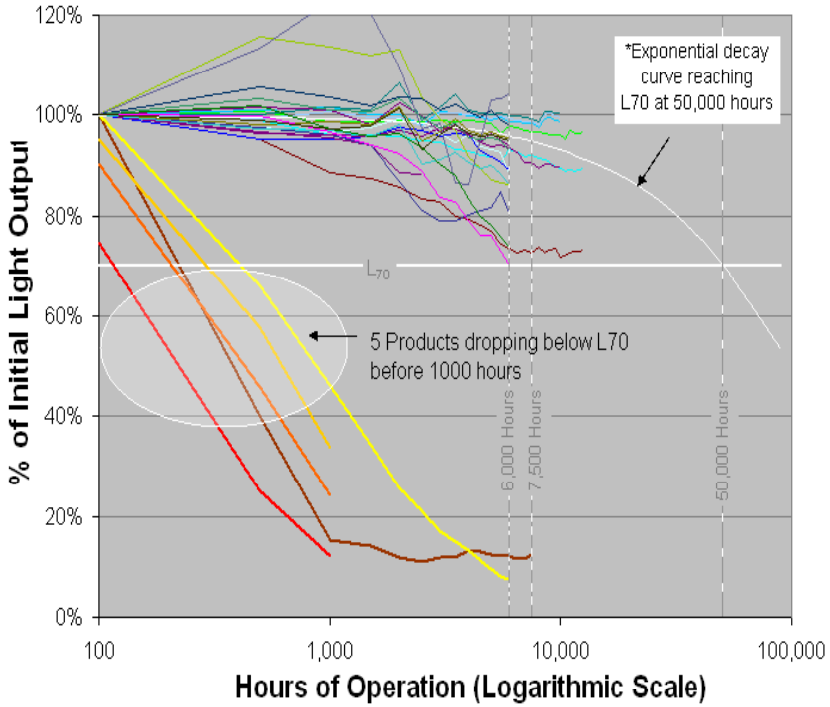
Context for Deep-Dive Testing

- CALiPER Long-Term Testing
- ENERGY STAR for SSL
- ASSIST Recommends Research
- IESNA efforts
- ANSLG working groups
- NEMA working groups
- CALiPER Roundtable Meetings



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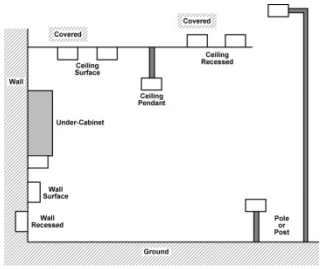
ENERGY STAR for SSL Use of TMP

- Implied and explicit application of TMP concept
  - Color maintenance requirements
  - Thermal management requirements
  - Package/module/array requirements for lumen maintenance
  - Relies on LM-80 concept as basis for lumen depreciation criteria
- Lumen maintenance qualification procedure: Component performance
  - Package/module/array tested using LM-80, meets criteria
  - Temperature Measurement Point (TMP_{LED})
    - Prescribed by package/module/array manufacturer
    - Accessible for thermocouple measurement
  - TMP_{LED} meets spec (as per LM-80 report)
  - Drive current meets spec (as per LM-80 report)



ASSIST Recommends Suggestions

1. Recommendations for Testing and Evaluating White LED Light Engines and Integrated LED Lamps Used in Decorative Lighting Luminaires[1]
   - Characterizing LED engine performance as a function of operating temperature
   - Estimating LED engine performance in actual conditions

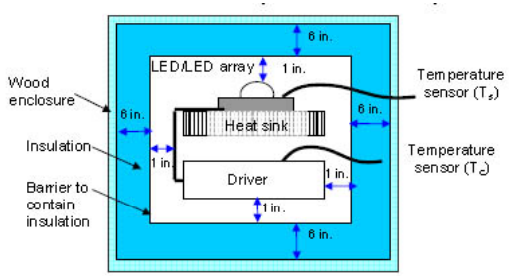


Figure 5. Schematic of the LED engine placed inside the test chamber for measuring worst-case temperatures.

2. "Developing a relationship between LED light engine performance parameters (flux, efficacy, CCT, CIE x, y, and CRI) and the board temperature (Ts) is useful for estimating the performance of a light engine in any light fixture"[2]
   - Testing LED engines at three temperatures 40%, 60% and 80% of Tj max

1. Lighting Research Center, May 2008
2. ASSIST Recommends Directional Lighting and Light Engines, Lighting Research Center, 2008.

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Related Standards & Industry Efforts

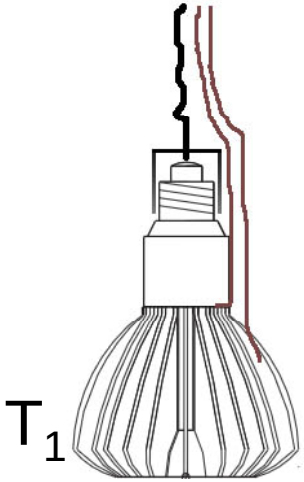
- IESNA LM-80
  - LED module lumen depreciation testing—specifics on test parameters
- IES LM-XX1 Methods for the measurements of high power LEDs
  - In draft development
- IES LM-XX2 LED “Light Engine” measurements
  - PIF for approval
- ANSLG working group
  - LED package size standardization in support of interconnects
- NEMA LSD-45
  - Sub-assembly interfaces for LED modules in luminaires
- NEMA ANSI C78-09 WG
  - Standard for characterizing and testing thermal, electrical, and mechanical properties of interface/base

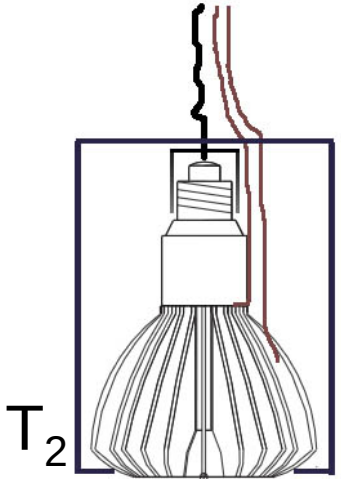
Proposed Testing Initial Requirements

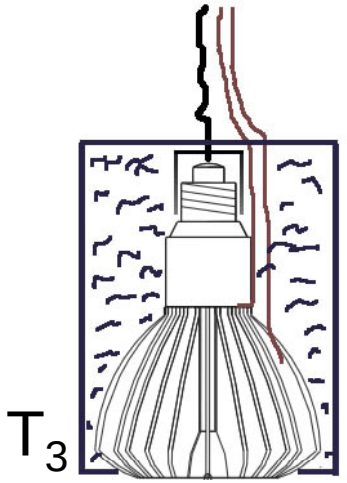
- Preconditions
  - Minimum 10 samples of each lamp type (small integral replacement lamps)
  - Samples with access to manufacturer TMP_{LED}
  - Available manufacturer literature for LED device
    - Specifications (including I_f, V_f characterizations)
    - LM-80 style results
    - Design recommendations (including thermal management recommendations, T_s--T_j correlations…)
    - Color and current performance dependencies
  - Manufacturer (device and SSL integral lamp) agreement to participate
    - De-identified findings (to be decided)

Proposed Long-term Operation Set-Up

- Each product to be operated 8000 hours
- Samples of each product at three different temperatures during 8000 hours of operation
  - T_1
  - $T_2 = T_1 + \sim 20C$
  - $T_3 = T_2 + \sim 20C$
- TMP_{LED} and T_{case} measured
- Preferably no active heating of fixtures







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Proposed Testing of Samples

- All photometric testing using LM-79,
  - Ensure long-term calibration, consistency of equipment
- At outset (t_0)
  - All samples tested under 25°C environment
  - All samples tested under long-term operation condition (in semi-insulated cans and highly insulated cans)
- Every 500 hours
  - All samples tested under long-term operation condition (in semi-insulated cans and highly insulated cans)
- After 8000 hours of operation (t_{8000})
  - All samples tested under long-term operation condition (in semi-insulated cans and highly insulated cans)
  - All samples tested under 25°C environment

Examples of Questions Under Study

- How much do color characteristics vary with operating temperature?
  - Does that correspond to package/module/array specs?
- How much does lumen depreciation vary with operating temperature?
  - Does that correspond to package/module/array specs?
- Are some temperature dependent performance differences reversible?
- How much variation do we see between samples?
- What realistic challenges will manufacturers and testing labs face in
  - Developing related testing methodologies?
  - Implementing the TMP_{LED} concepts?
  - Using these concepts to increase product quality?

Time-Line for Deep-Dive Testing

NOW

- ARRA funds now allocated for study
- Identification of manufacturers and products for study
- Determination of testing laboratory
- Prepare and verify test procedure & long-term operational conditions
- 8000 hours of operation
  - LM-79 integrating sphere testing every 500 hours
- Analyze correlations between LED device specifications and in situ performance
  - At different temperatures and over time
- Share results with manufacturers, experts and standards committees

THANK YOU

- Please send your constructive ideas and suggestions regarding this new study

- Jeff McCullough, PNNL
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